Failure Analysis Associates

Cell Phone Usage
At Gasoline Stations

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Executive Summary

Exponent Failure Analysis Associates (FaAA) was retained by Motorola to investigate the potential hazards associated with the use of cell phones at gasoline service stations. Based on a review of literature concerning alleged fires of this nature, a review of standards and codes relating to electronic equipment at gasoline stations, the fundamental physics of combustion and ignition processes, and prior work on the ignition characteristics of equipment such as cell phones, FaAA has reached the following conclusions.

1. The use of a cell phone at a gasoline filling station under normal operating conditions represents a negligible hazard. Even at stations without vapor recovery systems, gasoline vapors will not collect in regions of expected cell phone operation. The small openings present in a typical cell phone casing act to limit the prospects for developing a combustible concentration at any site theoretically capable of acting as an ignition source, and may also act to quench flames and prevent their propagation if the vapors are ignited.

2. The possibility of abnormal operation of both the gasoline pump and the cell phone presents a potential hazard. Gasoline spills or sprays create larger flammable vapor volumes and the potential to initiate a fire of sufficient size and duration to ignite other combustible materials. The cell phone would still need to be within an area having a flammable mixture, for example lying on the ground near the filling operation or a spill. In addition, if the phone has no competent ignition source during normal operation, something would have to go wrong with the phone to provide a competent ignition source.

3. Published literature contains no credible evidence of cell phones igniting a fire at a gasoline station. Given the exposure (number of phones used at filling stations over the years throughout the world) and the lack of any confirmed incidents, the past performance of cell phones in this regard is outstanding. The likelihood of a cell phone starting a fire at a gasoline station is very remote. Automobiles (which have numerous potential ignition sources) pose a greater ignition hazard. Finally, other potential ignition sources are present, such as a static discharge between a person and a vehicle.

Introduction

Exponent Failure Analysis Associates (FaAA) was retained by Motorola to investigate the potential hazards associated with the use of cell phones at gasoline service stations. The following report describes the results of our investigation. It begins with a brief discussion of the relevant fundamental physics of combustion, ignition, and vapor propagation processes. This report then discusses the environment encountered at a gasoline station, including the physics accompanying tank filling, the relevant codes, and standards for electronic equipment at service stations, and the literature on alleged incidents at fueling stations. This report goes on to discuss the cell phone as a potential ignition source and concludes with a brief discussion, for comparison, of the potential ignition sources encountered with automobiles and drivers.

Physics of Combustion and Vapor Propagation

For combustion to occur four elements must be present: an oxidizer, a fuel, an ignition source, and free radicals to propagate the chemical reaction. In the environment of a gasoline station, the oxygen in the air acts as the oxidizer. Gasoline vapor, either emitted during the fueling process or evaporated from a spill, is the fuel. Competent ignition sources would be a spark or very hot surface. Free radicals will be present when gasoline vapors in air are ignited.

Not all fuel/air mixtures are ignitable, nor will all sparks or hot surfaces ignite all flammable mixtures. Whether a mixture will ignite and/or sustain a flame is determined by competition between the rate of heat generation where the air-fuel mixture is reacting (reaction zone), and the rate of heat transfer away from this reaction zone. If the rate of heat generation is higher, the temperature in the reaction zone rises and accelerates chemical reactions, ultimately resulting in a self-sustaining, propagating combustion zone or flame. If the rate of heat generation is lower than the rate of heat transfer away from the reaction zone, the reaction zone will cool, the chemical reaction rates will slow, and any reactions or flames will extinguish. The rates of heat generation and heat transfer are affected by numerous conditions including the fuel/oxidizer ratio (stoichiometry), the geometrical configuration of the system, and characteristics of the environment. These are discussed below in some detail.

Flammability Limits

Fuel/air mixtures have two flammability limits: a lower explosion limit (LEL) or lean limit, where the concentration of fuel is too low to allow flame propagation, and an upper explosion limit (UEL) or rich limit, where the concentration of fuel is too high and the available oxygen is too low to allow flame propagation. At each limit, the scarcity of one reactant results in a rate of heat generation that is just balanced by the rate of heat transfer away from the reaction zone. The flammability (explosive) limits of a fuel/air mixture are thus the prime measures for ascertaining whether a particular mixture is combustible. If the fuel concentration in a particular gas mixture is between the LEL and UEL, that mixture is ignitable if a competent ignition source is present. If the fuel concentration in a particular gas mixture is outside the range bounded by the LEL and UEL, then that mixture will not ignite.

Every fuel has unique flammability limits in a specific oxidizing atmosphere. These limits are determined by the fuel's specific combustion chemistry and the heat transfer properties of the surrounding atmosphere. Since detailed combustion chemistry can be very complex, flammability limits are determined empirically with standardized tests.[1] Gasoline is a mixture of hydrocarbons of various types[2] as well as other additives. Though values may vary for different grades and formulations of gasoline, NFPA–325[3] quotes general lower and upper flammability limits of 1.4% and 7.6% by volume in air at ambient conditions. To put these numbers in some perspective, OSHA has set the PEL (Permissible Exposure Limit) at 300 ppm (0.03%), and their STEL (Short-Term Exposure Limit) at 500 ppm (0.05%). OSHA[4] cites studies showing that exposure to concentrations between 500 and 900 ppm for one hour produces dizziness. While an odor threshold for gasoline is not absolute since its composition and people's sensitivity can vary, 3M[5] lists a value of 0.3 ppm (0.00003%). Thus the concentration of gasoline vapors in air at the LEL is several orders of magnitude greater than the point at which a person will smell gasoline, and also is far greater than the concentration ceilings that OSHA prescribes for workers.

Quenching Distance

A combustion reaction that is confined to a small opening or to the interior of a narrow space will lose heat or free radicals to the walls of the confining structure. This loss of heat or free radicals can prevent self-sustained combustion of otherwise flammable vapors. Flame extinction by this form of heat loss or radical loss is called "quenching." Quenching distance is a measure of the largest opening through which a flame will not propagate. The quenching distance of a specific mixture depends on the mixture composition, the characteristics and geometry of the surfaces surrounding the opening, and the atmospheric conditions (e.g. pressure and temperature). Quenching distance is an empirically determined parameter. For nearly stoichiometric mixtures (mixtures that are neither rich nor lean) of various hydrocarbons in air under atmospheric conditions, the quenching distance between electrodes is approximately 2

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1 ASTM E681 describes a standard test method for determining flammability limits.

2 Mobil Oil Corp., 15024-34 Automotive Gasoline, Unleaded, Material Safety Data Bulletin.

3 NFPA 325, "Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids," 1994.

4 OSHA Preambles, Air Contaminants (29 CFR 1910.1000) VI. Health Effects Discussion and Determination of Final PEL. www.osha_slc.gov/Preamble/AirCont_data/AIRCON6.html.

5 3M Occupational Health and Environmental Safety Division, 1990 Respirator Selection Guide, St. Paul MN, p. 20., 1990.

mm.[6] We therefore expect that a flame will not propagate through a flammable gasoline mixture through channels or openings that are significantly smaller than 2 mm (0.08 inches). In the context of electrical equipment, openings and gaps significantly smaller than 2 mm can prevent the propagation of a flame even if there is an interior ignition source.

Ignition Sources

A competent ignition source, assuming a combustible mixture is present, could be either a hot surface or a spark. For a hot surface to ignite a flammable mixture, its temperature must be above the auto-ignition temperature of the mixture. The auto-ignition temperature is determined experimentally by uniformly heating a specified volume of the mixture to different temperatures until full reaction is observed. NFPA-325 lists auto-ignition temperatures for gasoline that range from 536°F to 853°F. In practice, the hot surface temperature needed for ignition may be hundreds of degrees hotter than the auto-ignition temperature, since gases in contact with the surface will heat and convect away before reaching a temperature suitable for ignition propagation. The auto-ignition temperatures are well above the normal operating temperatures of any cell phone components; so hot surfaces would be an ignition concern only during a malfunction of the phone or battery, or if the battery's energy were used to heat some other object.

Electrical sparks are the result of a discharge of energy through a gap. The parameter of most significance for prediction of ignition is the spark energy. For any given vapor-air mixture, there is a "minimum spark ignition energy". Below this energy level, a spark will be incapable of igniting that specific vapor-air mixture. Minimum spark ignition energies are tabulated for specific fuel-air mixtures at specific atmospheric conditions, and are based on optimal electrode geometry and separation. The minimum spark energy required to ignite gasoline vapors is approximately 0.2 mJ at the optimum mixture ratio[7] (slightly rich of the stoichiometric mixture ratio) and optimum electrode spacing. The spark energy required for ignition increases as the mixture ratio departs from the optimum mixture ratio and the electrode spacing departs from the optimum spacing. As discussed above, the quenching distance for gasoline vapors is approximately 2 mm.

The energy available in a spark can be either calculated or experimentally measured. The sparking would occur, in the case of cell phones, if a current-carrying connection were opened. (Sparking is not a factor during the closing of a circuit because of the low voltages present in the cell phone.) To assess whether a generated spark can be considered competent to ignite a flammable mixture with a phone-battery combination, the spark energy should be computed or measured, and the distance between contact points during sparking determined, and these values compared to the minimum spark ignition energy and the quenching distance.

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[6] Glassman, I., Combustion, 2nd Edition, pp. 312-313, 1987.
[7] Glassman, I., Combustion, 2nd Edition, pp. 486-489, 1987.

Vapor Propagation

Gasoline vapors propagate in the atmosphere through a variety of physical processes. The slowest process is by diffusion. Other processes include forced convection (e.g., air currents or turbulent mixing), and buoyancy induced convection (e.g. heavier than air vapors descending). For vapors to enter an enclosure through an opening in a quiescent environment, diffusion would be the limiting process. Gasoline is a mixture of compounds, and a single value for the diffusivity of gasoline vapor in air is not definable. However based upon the diffusivities of pure hydrocarbons, we can roughly estimate the diffusivity, D, of gasoline vapors to be about 0.1 cm^2/sec.[8] A characteristic time for gasoline vapors to diffuse a distance of approximately an inch would be on the order of a minute. When considering enclosed spaces, such as the air passages inside a cell phone or battery, the concentrations of vapors outside and inside the phone will equilibrate by diffusion (in a quiet environment) and the minimum time for this to occur can be estimated based on the shape and dimensions of the enclosed space. A non-quiescent environment is one where the vapor propagation rate is dominated by one of the other processes mentioned. Experimental approaches are most effective to accurately quantify the time required to develop a flammable mixture in the interior of a specific cell phone design for a given set of circumstances. However, for a cell phone in a quiescent flammable environment, it could require on the order of minutes for sufficient gasoline vapors to diffuse into the enclosed spaces of a cell phone, and to build up to a flammable mixture.

Buoyancy has a strong effect in propagating gasoline vapors. Gasoline vapors are three to four times denser than air,[9] causing them to sink when released. Even at the LEL (the lowest ignitable fuel concentration), the fuel / air mixture is roughly 3%-4% heavier than air and will descend if a plume is released. Ignition sources closer to the ground therefore present a greater hazard than those higher up. Air currents and turbulence caused by wind, passing cars, and people will also increase the mixing of released vapors, diluting them to concentrations below the LEL.

Gasoline Stations

The concentration of gasoline vapors in an automobile's fuel tank is above the UEL. The concentration of these vapors is determined by the vapor pressure of the fuel in the tank. The vapor pressure, in turn, depends on the formulation (which varies with supplier, region, and time of year), temperature, and other factors. A typical value for the vapor concentration might be 50%. As the tank is filled, the vapors are displaced by liquid fuel. A characteristic flow rate for liquids (and hence vapors) would be 10 gallons per minute. At some locations, vapor recovery systems capture the bulk of the displaced vapor (California Air Resources Board certification requires a fleet average vapor recovery of 95% or better). If there is no vapor recovery system, the gasoline vapors will exit the nozzle at about the same rate as the tank is filled (e.g. 10 GPM),

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8 Perry's Chemical Engineers' Handbook, 6th Edition, McGraw-Hill Book Company, San Francisco, Sec. 3, pp. 256 –257, 1984.

9 NFPA-325, "Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids," 1994.

and will tend to descend to the ground and disperse. In the atmosphere, dilution causes the concentration of these vapors to decrease below the LEL. Calculating the regions where the vapor-air mixture is flammable is a complex function involving many factors. However, as an example, assume that a 20-gallon tank is filled, and 20 gallons of 50% gasoline vapor are emitted into the air surrounding the filler neck. If we further assume that the gasoline vapors remain within 1.5 ft of the ground, are uniformly mixed, and disperse radially to a distance of 20 ft (dimensions corresponding to the region identified by NFPA 70, the National Electrical Code, as Class I, Division 2 - discussed below), then the resulting mixture will be approximately 0.07% gasoline vapor (below the LEL of 1.4%). Even if the gasoline vapors only disperse radially to a distance of 10 ft, the resulting mixture would be approximately 0.3% gasoline vapor. These values are given for illustrative purposes only, since the vapor concentrations will not be uniform but will vary with time, height, and distance from the source, and will be affected by other factors such as wind or turbulence from vehicles or people passing by.

If gasoline is leaked or is spilled during the filling operation, additional vapor will be produced. The vapor will also descend and stay low to the ground due to its greater density. If the spill or leak is significant, then ignition of the vapors will create a pool fire potentially capable of igniting other materials in the vicinity.

Codes and Standards

The National Fire Protection Agency (NFPA)[10] and the Uniform Fire Code (UFC)[11] have standards for service stations reflecting the hazards present from expected operating conditions. The NFPA 30A Code, Section 9-9 requires that warning signs be conspicuously posted in the dispensing area incorporating the following wording: “WARNING – It is unlawful and dangerous to dispense gasoline into unapproved containers. No Smoking. Stop Motor.” These warnings are designed to prevent large spills of gasoline, and to prevent ignition of low-lying vapors from sources such as discarded matches or operating automobiles.

Both the NFPA and UFC codes classify various regions around gasoline service stations and dispensing devices for the purposes of installation and utilization of electrical equipment under the classes and divisions defined in Chapter 5, Article 500 of the NFPA 70, National Electrical Code[12]. The figures from NFPA-30A are attached (Table 1, and Figure 1). They show that the area within the dispenser enclosure is rated as an NEC Class I, Group D, Division 1 area. The area within 18 inches surrounding a dispenser, and 18 inches above the ground level to a distance of 20 feet surrounding the dispenser is rated an NEC Class I, Group D, Division 2 area.[13]

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[10] NFPA 30A, “Automotive and Marine Service Station Code,” 1996.

[11] UFC, Article 52, “Motor Vehicle Fuel-Dispensing Stations,” 1997.

[12] NEC, Article 500, 1999.

[13] Articles 501 and 504 of the NEC define requirements for intrinsically safe electronic devices in Class I, Division 1 and Class I, Division 2 areas.

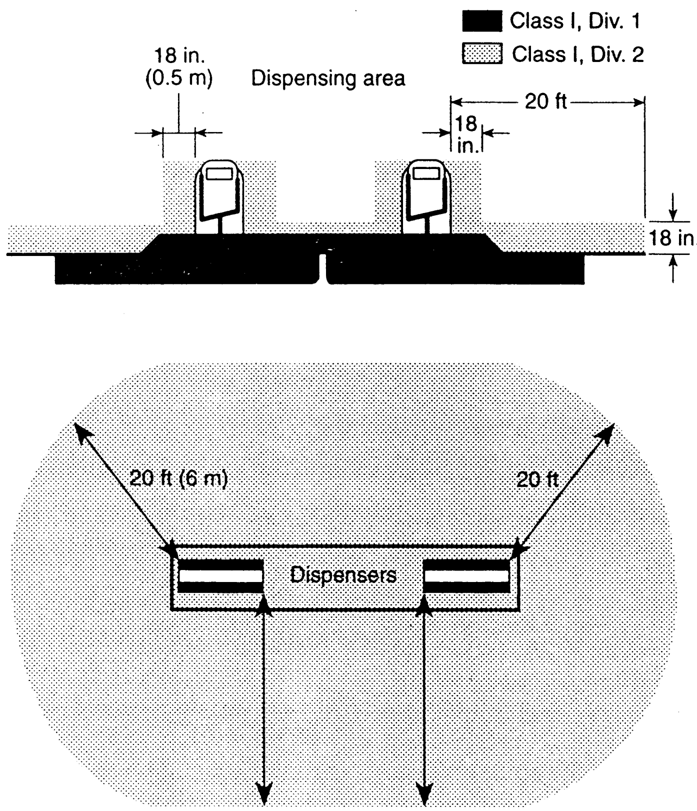

Figure 1. Classified areas adjacent to dispensers as detailed in Table 1 [Table 7, NFPA 30A–1996 "Automotive and Marine Service Station Code"].

The NEC rating system defines Class I locations as "those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures." Group D includes those locations in which gasoline vapors are or may be present. Division 1 locations are those in which:

1. "ignitable concentrations of flammable gases or vapors can exist under normal operating conditions; or
2. ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or
3. breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment..."

Division 2 locations are those in which:

1. "volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or
2. ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or
3. that is adjacent to a Class I, Division 1 location, and to which ignitable concentrations of gases or vapors might occasionally be communicated unless such communication is prevented…"

In Article 500, the NEC specifies a variety of "acceptable protection techniques" for electrical equipment in classified locations. These techniques include a product being designated explosion-proof, intrinsically safe, or nonincendive. Each of these "protection techniques" references a series of standardized tests that a product must withstand.[14] The nonincendive designation is the least strict of the acceptable techniques: it is acceptable in Division 2 locations, but not in Division 1 locations. A nonincendive designation requires that circuits and components under intended operating conditions be incapable of causing ignition of a specified flammable gas- or vapor-air mixture. In addition, in Article 501, the NEC specifies minimum standards for electrical equipment construction and installation for use in Class I, Division 1 and Division 2 areas.

FaAA has not evaluated whether any cell phones or batteries produced by Motorola or by any other manufacturer meet the requirements for Class I, Group D, Division 1 or 2 locations. However, in order to encounter an NEC classified location (Division 2), a cell phone would have to be held close to the fuel dispenser, or be lying on or within 1½ feet of the ground and within 20 feet of the dispenser. Both of these are possible scenarios, but do not represent typical cell phone usage conditions. It is very unlikely that a gasoline station customer would be able to introduce a cell phone into a Division 1 area.

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[14] ANSI/UL 1203 "Explosionproof and Dust-Ignitionproof Electrical Equipment for Use in Hazardous (Classified) Locations," ANSI/UL 913 "Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous Locations," UL 1604 "Electrical Equipment for Use In Class I and II, Division 2, and Class III Hazardous (Classified) Locations."

Literature on Alleged Incidents at Fueling Stations

The literature we reviewed was filled with articles expressing concerns and opinions on the potential hazards of cell phone use at gasoline stations.[15 - 23] However, our search uncovered no instances of fires or explosions that were confirmed to have been caused by the operation of a cellular phone in a gasoline station. While there have been reports of cellular phones allegedly starting fires in gasoline stations, further investigation showed these reports to be unsubstantiated.[24, 25]

Cell Phones as an Ignition Source

FaAA has not undertaken an analysis of every model and style of cell phone or related communication device produced either by Motorola or any other manufacturer. However, we can provide some general guidelines for evaluating ignition hazards. For the cell phone to be considered a competent ignition source, it would need to either:

a) discharge enough energy via a spark in a geometry where the gaps are larger than the minimum quenching distance, or

b) it must have a component or area heated to a temperature high enough for hot surface ignition to occur.

As discussed earlier, the minimum spark energy required for ignition is 0.2 mJ (0.0002 Joules), and the minimum quenching distance is about 2 mm. The minimum temperature for hot surface ignition is geometry dependent, but will be hotter than the auto-ignition temperature of gasoline, which is about 536 ºF. Both of these types of ignition sources are discussed below.

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15 Associated Press, "Cell phones to be banned at gas stations in Finland as safety debate continues," January 14, 1999.
16 Kathy Chen, "Latest Urban Legend? Cell Phones Igniting Fumes at Gasoline Stations," *The Wall Street Journal*, July 9, 1999.
17 Paul Zucker, The Gale Group, "Don't Use Cellular Phones at Service Stations," April 22, 1993.
18 Associated Press Information Services, "BP Amoco Curbs Cellular Phone Use," October 8, 1999.
19 Associated Press Information Services, "Report: BP Amoco to Ban Cell Phones," October 7, 1999.
20 The Gale Group, "Shell bans mobile phones on forecourts," July 9, 1993.
21 *Kyodo News International, Inc*., "Cellular Phones May Cause Fire at Gas Stands," June 7, 1999.
22 WTN 1204-99.
23 *Bridge News*, *Sao Paulo*, "KRF Brazil newspaper summary: new law restricts cellular phone use," September 11, 1996.
24 *The Hong Kong Standard*, "Mobile phone ruled out as cause of petrol station blast," March 4, 1999.
25 *Newsbytes*, "Hong Kong advises against mobile phone use in gas stations," June 13, 1999.

Spark Discharge

The possibilities for a cell phone to create a spark are limited, and include:

a) Pressing buttons

b) Disconnecting the battery

c) Vibrator mode

d) Accidental shorting of the battery terminals

e) Electrostatic discharge

In each of these circumstances, energy is stored either in the electromagnetic fields associated with the current, or in electrostatic fields (e.g. capacitors). This energy might result in the release of a spark that jumps between the terminals when a circuit is opened (for example by the release of a pressed key).

If the battery is disconnected during operation, the energy dissipated in any spark will be related to the current drain on the battery, and the circuitry connected to the battery. This energy will be dependent on the phone type and mode of operation. The sparking, if any, will occur between the battery contacts and the cell phone contacts, an area enclosed in most phones and therefore unlikely to have a combustible mixture present at the moment of sparking.

The vibrator in some phones is a tiny motor with an eccentric weight. Depending on the type of motor, for example one with brushes, sparks may be generated with operation. The motor is enclosed within the phone housing, and is therefore unlikely to be in contact with a combustible mixture of gases if the phone is placed briefly in a combustible atmosphere.

Accidental shorting and opening of the battery terminals by some external agent is a remote possibility when in use. Motorola batteries traditionally have over-current protection (and some have diode protection) that limit or prevent discharging current through the exposed external terminals in the event of a direct short. Furthermore, the terminals are guarded, so a short across the terminals is very unlikely. Thus, sparking due to external shorting of the battery terminals is difficult to achieve in practice.

Electrostatic discharge might arise from triboelectric processes, such as rubbing a plastic object against fabric. Materials vary in their ability to collect a static charge. Materials that are more conductive have a lesser ability to build up a localized static charge. FaAA has not performed any investigations into the capacity for static charge buildup by cell phones or batteries made by Motorola or any other manufacturer.

In some of the articles listed above, the energy during transmission was identified as a potential ignition source. FaAA has seen no credible evidence of this being an ignition source.

Hot Surface Ignition

As discussed earlier, the surface temperature needed to ignite a combustible mixture of gasoline vapor and air will be higher than the auto-ignition temperature. A very conservative estimate for the hot surface temperature needed for ignition would be the auto-ignition temperature for gasoline vapor-air mixtures, which is at or above 536 F. Under normal operation, no surfaces on or in the phone or battery reach temperatures close to this value. Therefore, hot surface ignition for a normally operating phone is not a consideration.

Under fault conditions, a component or components can reach temperatures above the auto-ignition temperature. One fault condition would be a short circuit between cells internal to the battery, or a short circuit inside a cell, such as a Li ion cell. In these cases, components might reach temperatures high enough to serve as ignition sources. The battery is generally well enclosed, and therefore getting a combustible mixture inside the battery housing would be difficult. Furthermore, the combustible mixture would have to be present during the brief period of time that the cells short. The probability of this happening is very remote.

Another fault condition might be overheating and thermal runaway of a component or components inside the cell phone. Generally, this would be a transient event, and would occur within the enclosure of the cell phone. It is very unlikely that a combustible mixture of gasoline vapor and air would enter the phone enclosure, and furthermore that it would occur at the moment that a component overheated. There may be rare circumstances where the heat generated by the component overheating breaches the enclosure. These circumstances are exceedingly rare and do not pose a significant concern, especially when the overheating must coincide with the phone being positioned in a combustible mixture at the moment of component failure.

Motor Vehicles as Ignition Sources

The engine in a motor vehicle can act as an ignition source if operated in a combustible environment. Some potential ignition sources are: alternator brushes, starter motor assembly, electric fans on the radiator, grounded spark plug wires, and even hot surfaces on an exhaust system of an abnormally performing engine. Most of these sources would be closer to the ground than a cell phone in operation, and thus closer to any combustible mixtures of gasoline vapor and air resulting from filling operations or a spill. Another possible ignition source is static discharge between the driver and the car that might occur in dry weather. Such discharges, which would occur when the driver first touches the body of the car, might happen in the vicinity of the filler opening. The spark energy associated with electrostatic discharge

(ESD) by a person depends upon many factors. For comparison purposes, electrostatic discharge (ESD) simulator requirements can reach 10 mJ or higher.[26]

Conclusions

Based on our analyses, the ignition of flammable vapors at a gasoline station by a cell phone is a highly unlikely event. While the cell phone cannot be ruled out as a potential ignition source under all physically possible scenarios, numerous other more likely ignition sources are present during the normal process of refueling a vehicle. This conclusion is supported by the following observations:

1. No confirmed incidents of fires at gasoline stations started by cell phones have been found.

2. Combustible vapors produced during fueling will not generally collect in regions of probable cell phone operation.

3. The small openings present in a typical cell phone's casing will limit the concentration of any combustible vapors present within the cell phone. In addition, narrow gaps may quench any flames if they are ignited internally, preventing their propagation outside the enclosure.

4. A combination of events would have to occur in order to create an accident, including:

   a. the placement of the cell phone in a flammable mixture for a sufficient length of time to allow a flammable mixture to form inside the cell phone,

   b. a fault, malfunction, or spark generation in the cell phone that would produce a competent ignition source that could propagate outside of the battery or phone enclosure.

   (A spill or dispersion of liquid gasoline on or near the phone would increase the hazard by increasing the likelihood of having combustible vapors present at the ignition source.)

5. Automobiles and the process of refueling provide potential ignition scenarios that are more likely to result in flammable vapor ignition.

In summary, the enclosures protecting the battery and cell phones, the low voltages and current drains of these components, the geometry of their interconnections, and the physics of electrical discharge and vapor diffusion strongly direct against the cell phone and battery acting as an ignition source while at a service station.

[26] DOD-HDBK-263, IEC 801-2.

Table 1: From NFPA 30A – 1996 "Automotive and Marine Service Station Code"

Location	NEC Class I, Group D Division	Extent of Classified Area[1]
Underground Tank Fill Opening	1	Any pit, box, or space below grade level, any part of which is within the Division 1 or 2 classified.
	2	Up to 18 in. above grade level within a horizontal radius of 10 ft from a loose fill connection and within a horizontal radius of 5 ft from a tight fill connection.
Vent — Discharging Upward	1	Within 3 ft of open end of vent, extending in all directions.
	2	Area between 3 ft and 5 ft of open end of vent, extending in all directions.
Dispensing Device[2,3] (except overhead type)[4]		
Pits	1	Any pit, box, or space below grade level, any part of which is within the Division 1 or 2 classified area.
Dispenser	2	Within 18 in. horizontally in all directions extending to grade from (1) the dispenser enclosure or (2) that portion of the dispenser enclosure containing liquid handling components.[3]
Outdoor	2	Up to 18 in. above grade level within 20 ft horizontally of any edge of enclosure.
Indoor with Mechanical Ventilation	2	Up to 18 in. above grade or floor level within 20 ft horizontally of any edge of enclosure.
with Gravity Ventilation	2	Up to 18 in. above grade or floor level within 25 ft horizontally of any edge of enclosure.
Dispensing Device — Overhead Type[3, 4]	1	The area within the dispenser enclosure, and all electrical equipment integral with the dispensing hose or nozzle.
	2	An area extending 18 in. horizontally in all directions beyond the enclosure and extending to grade.
	2	Up to 18 in. above grade level within 20 ft horizontally measured from a point vertically below the edge of any dispenser enclosure.
Remote Pump — Outdoor	1	Any pit, box, or space below grade level if any part is within a horizontal distance of 10 ft from any edge of pump.
	2	Within 3 ft of any edge of pump, extending in all directions. Also up to 18 in. above grade level within 10 ft horizontally from any edge of pump.
Remote Pump — Indoor	1	Entire area within any pit.
	2	Within 5 ft of any edge of pump, extending in all directions. Also up to 3 ft above floor or grade level within 25 ft horizontally from any edge of pump.
Lubrication or Service Room — with Dispensing	1	Any pit within any unventilated area.
	2	Any pit with ventilation.
	2	Area up to 18 in. above floor or grade level and 3 ft horizontally from a lubrication pit.
Dispenser for Class I Liquids[3]	2	Within 3 ft of any fill or dispensing point, extending in all directions.
Lubrication or Service Room — without Dispensing	2	Entire area within any pit used for lubrication or similar services where class I liquids may be released.
	2	Area up to 18 in. above any such pit and extending a distance of 3 ft horizontally from any edge of the pit.
	2	Entire unventilated area within any pit, below-grade area, or subfloor area.
	2	Area up to 18 in. above any such unventilated pit, below-grade work area, or sub-floor work area and extending a distance of 3 ft horizontally from the edge of any such pit, below-grade work area, or sub-floor work area.
	Nonclassified	Any pit, below-grade work area, or sub-floor work area that is ventilated in accordance with 5-1.3.
Special Enclosure Inside Building Per 2-2	1	Entire enclosure.
Sales, Storage, and Rest Rooms	Nonclassified	If there is any opening to these rooms within the extent of a Division 1 area, the entire room shall be classified as Division 1.
Vapor Processing Systems Pits	1	Any pit, box, or space below grade level, any part of which is within Division 1 or 2 classified area or that houses any equipment used to transport or process vapors.
Vapor Processing Equipment Located within Protective Enclosures (*see 4-5.7*)	2	Within any protective enclosure housing vapor processing equipment.
Vapor Processing Equipment Not within Protective Enclosures (excluding piping and combustion devices)	2	The space within 18 in. in all directions of equipment containing flammable vapors or liquid extending to grade level. Up to 18 in. above grade level within 10 ft horizontally of the vapor processing equipment.
Equipment Enclosures	1	Any area within the enclosure where vapor or liquid is present under normal operating conditions.
	2	The entire area within the enclosure other than Division 1.
Vacuum-Assist Blowers	2	The space within 18 in. in all directions extending to grade level. Up to 18 in. above grade level within 10 ft horizontally.